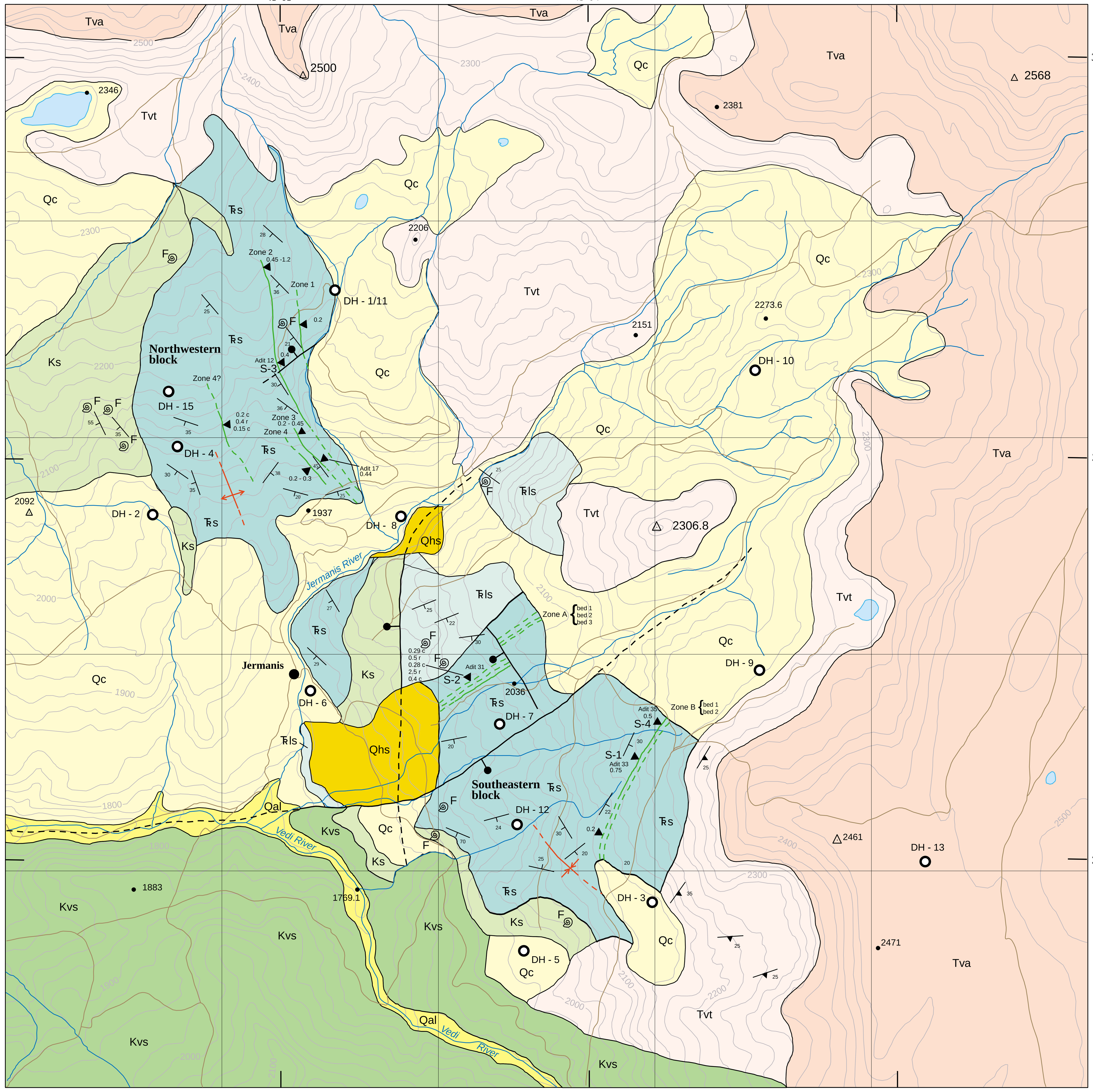
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES MAP MF–2350
Version 1.0
Pamphlet accompanies map



Base from 1954 Soviet 1:25,000 scale topographic map, J-38-7-A-a, Kelanlu
Original contour interval is 5 m
Projection Transverse Mercator
Coordinate System Gauss-Krueger, 1942

Scale 1:10,000
0 500 1000 m
Contour interval 25 m

Mapped by Michael E. Brownfield and Artur Martirosyan, October 1998
Modified from Atabekian and others (1996).
Digitized by Gourgen Malkhassian and Douglas W. Steinshouer

Manuscript approved for publication October 23, 2000

CORRELATION OF MAP UNITS

Qal, Qc, Qhs — Holocene — QUATERNARY
Tva — Pliocene; Tvt — Miocene — TERTIARY

Unconformity

Kvs, Ks — Upper Cretaceous — CRETACEOUS

Unconformity

TRs — Upper Triassic; TRls — Middle to Lower Triassic — TRIASSIC

DESCRIPTION OF MAP UNITS

Qal **Holocene alluvium**—Stream deposits consisting of boulders, gravel, sand, silt, and clay associated with the Vedi River. Total thickness of unit is unknown

Qc **Holocene deposits**—Includes colluvium, talus, and landslide deposits with minor stream deposits associated with small streams. Total thickness of unit is unknown

Qhs **Holocene hot spring deposits**—Five terraces of travertine were noted but mapped as a composite unit. Individual terraces ranges from 5 to 20 m thick

Tva **Andesite flows (Pliocene)**—Gray and pink andesite flows. Some flows have large (as long as 0.5 cm) phenocrysts of plagioclase. Total thickness of unit is about 350 m

Tvt **Ash flow tuff (Pliocene to Miocene)**—Unit can be divided into two parts. Lower part consists of white, coarse-grained ash-flow tuff containing pebble- to gravel-size clasts of quartz and pumice about 200 m thick. Lower part of unit also contains air-fall ash displaying thin to thick reworked beds of ash. Lower part reported to contain diatomaceous sediments (Atabekian and others, 1996). Upper part consists of dark-gray to light-gray, densely welded ash-flow tuff (as thick as 50 m) containing phenocrysts of biotite, quartz, plagioclase, and minor pumice fragments

Kvs **Upper Cretaceous volcaniclastic rocks**—Unit consists of marine sedimentary rocks that contain volcanic clasts of rock fragments and volcanic ash. Thick, cliff-forming units containing medium to coarse clasts of volcanic rock fragments in an altered tuffaceous matrix. Includes thick marine units of altered green and red tuff. Total thickness of unit is unknown but it may be more than 1,000 m thick

Ks **Upper Cretaceous rocks (lower Coniacian to Turonian)**—Consists of a basal red conglomerate (20 m thick), sandstone, siltstone, shale, and limestone. Lower unit contains rudistid limestone rocks (as thick as 25 m) interbedded with conglomerate and tuffaceous sediments (as thick as 60 m). Unit contains rudistid mollusks and gastropods (such as *Oligoptyxis undulata*, identified by Armenia Academy of Science). Upper part of unit consists of interbedded tuffaceous sandstone and siltstone (as thick as 130 m). Total thickness of unit is about 190 m

TRs **Coal-bearing rocks (Upper Triassic)**—Unit includes dark-olive-green sandstone, siltstone, and shale with zones of carbonaceous shale and coal. Unit contains both marine and nonmarine sediments. Brachiopods were found at two localities. In northwestern block unit is about 600 m thick, and in southeastern block unit is about 540 m thick. In northwestern block there are at least 4 coal zones containing coals ranging from less than 0.1 to about1.2 m thick. In the southeastern block there are at least two coal zones containing coals ranging in thickness from less than 0.1 to 1.4 m. Coal beds are very lenticular

TRls **Limestone (Middle to Lower Triassic)**—Thick to thin, laminated, light- to dark-gray limestone with minor light- to dark-gray calcareous shale. Unit contains minor fossils. Total thickness is unknown but drill hole DH-7 penetrated 160 m

Contact—Approximately located

Fault—Dashed where inferred or concealed. Bar and ball on downthrown side

Anticline—Approximately located. Dashed where inferred

Syncline—Approximately located. Dashed where inferred

0.2 Adit 33 — **Coal bed or zone**—Approximately located. Dashed where inferred. Thickness, in meters, measured at triangle. Adit number shown where available

0.29 c / 0.5 r / 0.28 c / 2.5 r / 0.4 c — **Measured coal section**—Showing thicknesses of coal (c) and rock (r) in meters at triangle (Atabekian and others, 1996)

25 — **Strike and dip of bedding**

25 — **Foliation of ash-flow tuff**

S - 3 — **Coal sample collected for analysis**

F — **Fossil locality**

DH - 9 — **Drill-hole location**—Showing drill-hole name (Atabekian and others, 1996, drill hole DH - 9 is SKV - 9 in original report)

2461 — **Bench mark**—Showing elevation in meters

2471 — **Survey point**—Showing elevation in meters

Lake

River or stream

Road

Jermanis — **Center of village**

GEOLOGIC MAP OF THE JERMANIS COAL FIELD, CENTRAL ARMENIA

By
Michael E. Brownfield,[1] Artur Martirosyan,[2] Brenda S. Pierce,[3] and Edward A. Johnson[1]
2000

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Pamphlet to accompany
Miscellaneous Field Studies Map
MF–2350

INTRODUCTION

Purpose and Scope

The U.S. Geological Survey (USGS) signed a Participating Agency Service Agreement (PASA) with the U.S. Agency for International Development (USAID) to provide technical support to the Newly Independent States (NIS) of the Former Soviet Union in the development of oil, natural gas, and coal resources. The USGS and the Armenian government collaborated on a project to assess the coal resources of Armenia. The project included regional reconnaissance, detailed mapping, exploration drilling, geochemical analysis, and coal resource calculations. As a part of this program a field project was conducted in the fall of 1998 by the USGS to study the coal geology of the Jermanis coal field. This coal deposit, which is Triassic in age, is the oldest known coal in Armenia.

Location

Armenia, about 29,760 km^2 in size, is located in the lower Caucasus Mountain region of western Asia. The Jermanis coal field is located in the Ararat region of central Armenia about 60 km southeast of Yerevan, the capital of Armenia (fig. 1). The deposit is about 27 km northeast of the town of Vedi. The Triassic coal-bearing rocks are north and east of the village ruins of Jermanis (also known as Kelanlu) north of the Vedi River (see map). Pierce and others (1994) gave a reference of lat 39°58.27' N. and long 45°02.94' E. for an adit location in the northwest part of the coal field (Adit 12, map). Coal is present in two areas separated by the Jermanis River (see map). The Jermanis coal field is located on the southwest side of the Geghama Range. Elevation ranges from about 1,700 to more than 2,500 m in the coal field (see map).

Figure 1. Location map showing major cities, roads, and the Jermanis coal field in central Armenia.

The coal field is located in a small basin that is bordered by high volcanic plateaus on the north, west, and east. Large talus slopes mark the scarp below the plateau on the east and north. The study area is characterized as a rocky steppe that has been strongly dissected by numerous river systems. Several north- and northeast-trending tributaries of the Vedi River dissect the coal field. The major tributary in the coal field is the Jermanis River (fig. 2), which splits the area into northern and southern coal-bearing blocks.

Figure 2. Looking north along the Jermanis River in the Jermanis coal field. Upper Triassic rocks crop out on the right side of the stream. Rocks exposed in the upper left are Miocene tuffs.

Previous Geologic Studies

Numerous geologic investigations were conducted in the Jermanis coal field during and after the Former Soviet Union (FSU). Previous investigations of the Jermanis area included at least 25 coal exploration drill holes. Coal was first reported in Jermanis in 1921 by R.A. Krakhmalev (Atabekian and others, 1996) and in the same year the Yerevan Department of the Trans-Caucasus Geologic Exploration Party dug a few exploration adits and trenches and reported three coal beds about 0.4–0.5 m thick (Paffengolts, 1939). In 1939 and 1940 the biostratigraphy of the coal field was investigated by Nazarian (1939, 1941). Several adits and trenches were dug and three coal beds were exposed in the northwest part of the coal field, and two coal beds were also found in the southeast part. Tsetlin and Epstein (1940) estimated the resources to be only 328,000 metric tons and concluded that the Jermanis coal deposit was not economic. Mokrinski (1940) also concluded that the coal deposit was not economic but did recommend that more exploration be conducted in the northwest part of the field. Nazarian (1941) estimated the coal resources in the Jermanis coal field to be 2.0 million metric tons and concluded that the coal deposits had potential for production. From 1951 to 1953 the Jermanis coal field was evaluated by the Caucasus Coal Geologic Trust. A preliminary report was published by Rudzyanski (1953), which included a 1:5,000-scale geologic map and detailed stratigraphic sections of the coal-bearing rocks. Several other studies were conducted from the 1950's to the 1990's (Georgadze, 1955; Airapetian, 1967; Airapetian and Pogosian, 1968; Mkrtchian and Khachatrian, 1972) with the most recent exploration work from 1992 to 1994 (Atabekian and others, 1996). In the last study, seven shallow drill holes 20–50 m deep were completed; only one hole penetrated a thickness of 0.3 m or more of coal. Carbonaceous rocks were penetrated in several holes. In 1993, the study site was visited as part of a reconnaissance trip by geologists from the USGS and several coal samples were collected for analyses (Pierce and others, 1994).

Methodology

This study was initiated by translating a copy of the Atabekian and others (1996) report on the Jermanis coal deposit and digitizing their geologic map using USGS computer program GSMCAD (V.S. Williams, written commun., 1998). A topographic base map was digitized using GSMCAD and plotted at a scale of 1:10,000 with a contour interval of 25 m from a 1954 Soviet 1:25,000-scale topographic map (J-38-7-A-a, Kelanlu). Field work by the authors was conducted in the fall of 1998 and new samples were collected. As a result of this work, Atabekian and others' (1996) geologic map was modified (see map).

Determination of ash yields and chemical analyses on samples collected during this study was conducted by the USGS (Denver, Colo., laboratories). Coal samples were ashed at 525 °C prior to chemical analysis. Most element contents were determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES, 25 elements) or mass spectroscopy (ICP-MS, 17 elements). Mercury was analyzed by cold vapor atomic absorption spectroscopy (CV-AAS) whereas chlorine content was determined using ion chromatography, and selenium content was determined by hydride generation atomic absorption on whole coal samples.

Acknowledgments

Gaggik Papian and Irina Astvatsaturiants are thanked and acknowledged for the many hours they spent as interpreters and translating Russian and Armenian geologic reports into English for our study. We are grateful to Gourgen Malkhassian for the computer graphic support he provided during our study. Movses Kazarian is thanked for his long hours of logistical support and his interpreter skills during the project. We also thank Alla Papoyan of the Armenian Academy of Science for fossil identifications for this study.

GEOLOGIC SETTING OF THE JERMANIS COAL FIELD

The lithostratigraphic units exposed in the Jermanis coal field (fig. 3) range in age from Early to Middle Triassic to Quaternary (Atabekian and others, 1996). These rocks include Lower to Middle Triassic limestone, Upper Triassic coal-bearing deposits, Upper Cretaceous sedimentary and volcaniclastic rocks, Miocene to Pliocene volcanic rocks, and Quaternary deposits including alluvium, colluvium, landslide debris, hot spring deposits, and volcanic rocks. Major unconformities separate the Upper Triassic rocks from the overlying Upper Cretaceous rocks and the Upper Cretaceous rocks from the overlying Neogene volcanic rocks. Much of the study area is covered by Quaternary deposits, which obscured coal-bearing outcrops that were of interest to this study.

Stratigraphy

Lower to Middle Triassic limestone (TRls) crops out east of the Jermanis River; these are the oldest rocks exposed in the Jermanis coal area. The limestone unit consists of thick to thin, laminated, light- to dark-gray limestone beds interbedded with minor dolomite, light-gray oolitic sandstone, and light- to dark-gray calcareous shale beds. Some beds contain trace fossils (see map), and poorly preserved bivalve fossils are present. The unit is exposed just east of Jermanis where it is about 110 m thick. The total thickness of the limestone is unknown; drill hole DH-7 (see map) penetrated 160 m of limestone. Azarian (1962) identified fossils from limestone outcrops just northeast of DH-6 (see map) as Early and Middle Triassic.

Overlying the limestone are coal-bearing deposits (TRs) of Late Triassic age (Atabekian and others, 1996). The coal-bearing deposits include sandstone, siltstone, and argillite (claystone) with zones of carbonaceous shale and coal (figs. 4 and 5). The coal-bearing unit contains both marine and nonmarine facies. The light-gray to dark-gray and dark-olive-green sandstone beds contain fine to coarse grains of quartz, feldspar, and minor mica with either carbonate or clay cement. Sandstone beds commonly display cross-stratification (fig. 5). Nonmarine argillite is light- to dark-gray and black and, in places, grades into carbonaceous shale. The argillite contains fossil ferns, equisetum, cycaophyte, ginkgo, and conifer flora (Atabekian and others, 1996).

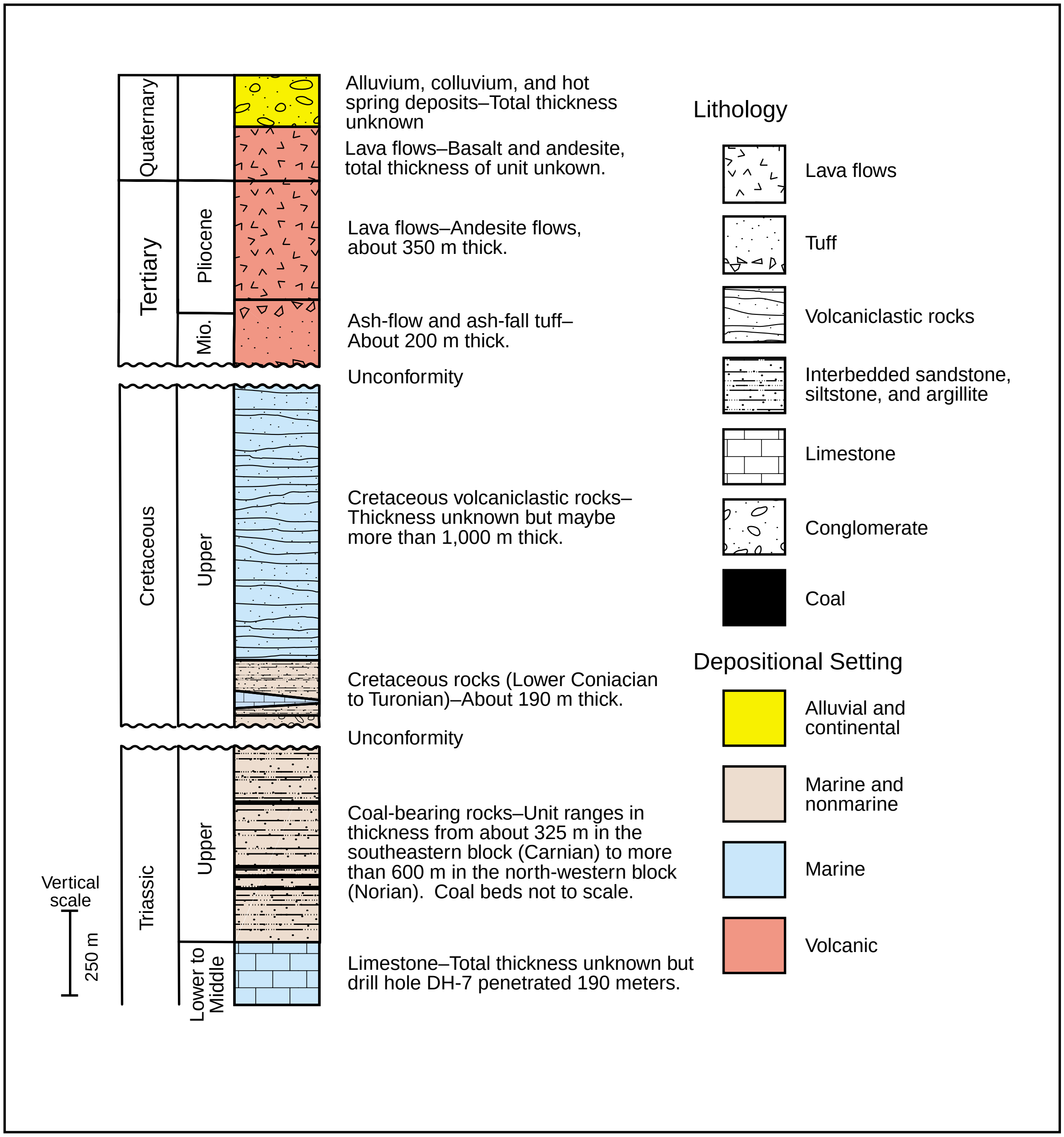

Figure 3. Generalized stratigraphic column of the lithostratigraphic units exposed in the Jermanis coal field, central Armenia. Mio.=Miocene. Thicknesses of rock units from Atabekian and others (1996).

Marine argillite contains abundant calcareous concretions, fossil brachiopods, and other mollusk fragments. Based on fossil evidence, the age of argillite rocks in the northwestern part of the study area is Norian whereas in the southeastern part it is Carnian (Azarian, 1962).

Rudzyanski (1953) described the Upper Triassic coal-bearing rocks in the northwestern and southeastern parts of the Jermanis coal field using drill-hole and outcrop data (tables 1 and 2). In his report the northwestern and southeastern parts of the coal area are called the northwestern block and the southeastern block, respectively.

In the northwestern block of the Jermanis coal field, the coal-bearing unit ranges from 535 to 620 m thick, and in the southeastern block the coal-bearing unit ranges from 525 to 545 m thick. Total thickness of the Upper Triassic deposits is unknown. In the northwestern block there are at least four coal zones containing coal beds ranging from less than 0.1 m to about 1.2 m thick (Atabekian and others, 1996). In the southeastern block there are at least two coal zones

Figure 4. Reddish-brown Upper Triassic deposits along the Jermanis River north of the village of Jermanis in the Jermanis coal field, central Armenia. Early to Middle Triassic gray limestone is in left center of photo.

Figure 5. Upper Triassic cross-stratified sandstone beds overlying gray argillite in the northwestern part of the Jermanis coal field, central Armenia.

containing coal beds ranging in thickness from less than 0.1 m to 1.4 m thick. The coal beds are very lenticular, contain partings, and are high in ash.

Cretaceous rocks of Turonian to Coniacian age (Ks) unconformably overlie the Triassic coal-bearing deposits in the Jermanis coal field. The Cretaceous unit consists of a thick red basal conglomerate and overlying beds of conglomerate, sandstone, siltstone, shale, and limestone (fig. 6). The basal conglomerate contains pebble- to boulder-size clasts of quartzite and limestone interbedded with minor red, fine- to coarse-grained sandstone. The matrix of the conglomerate consists of poorly sorted, hematite-cemented, very fine to very coarse grains of quartz and quartzite. The basal conglomerate is as thick as 20 m. Fossiliferous limestone beds are interbedded with red conglomerate, sandstone, siltstone, and shale in the lower part of the unit.

The limestone, which forms lenticular bodies as thick as 25 m and as much as 100 m long, contains rudistid bivalves and gastropods (such as *Oligoptyxis undulata*, Alla Papoyan, Armenian Academy of Science, oral commun., 1998) and are interpreted as rudistid reefs. The upper part of the Cretaceous unit contains fewer conglomerate beds and is best exposed in the northwestern part of the study area. Sandstone beds consist of fine to coarse grains of quartzite and quartz in a hematite-rich matrix interbedded with red siltstone and shale. Rarely, mollusk fossils are present in the upper part of the unit. Total thickness of the Upper Cretaceous unit is about 190 m.

Table 1. Composite stratigraphic section of Upper Triassic coal-bearing rocks, northwestern block of Jermanis coal field showing unit number in descending order, unit thickness, and cumulative thickness. Modified after Rudzyanski (1953) and Atabekian and others (1996). Drill-hole data from DH-1/11 (see map) was used to describe the lower part of the section and the upper part was based on outcrop data. Base of Upper Triassic coal-bearing rocks was not cut by drill hole DH-1/11. For description of coal zones see coal geology section.

Unit number	Description	Thickness (m)	Cumulative thickness (m)
8	Argillite, black; overlain by Upper Cretaceous red conglomerate.	40-50	40-50
7	Sandstone, dark-gray, fine-grained with minor thin argillite beds; greenish-gray sandstone found in upper part.	50-60	90-110
6	Sandstone, dark-gray, thinly laminated; interbedded with light- to dark-gray argillite with thin beds of carbonaceous shale and coal (coal zone 4).	20-40	110-150
5	Sandstone, light-gray, coarse-grained; laterally, sandstone beds grade into argillite; the upper part of the unit consists of two sandstone beds separated by clayey shales, carbonaceous shale, and coal (coal zone 3); the lower part of the unit consists of sandstone separated by gray argillite, carbonaceous shale, and coal (coal zone 2).	60-70	170-220
4	Argillites, dark-gray, thinly laminated with carbonized plant remnants; lower part contains fossil ammonites and pelecypods of Norian age.	40	210-260
3	Argillite, black, thinly laminated; interbedded with dark-gray sandstone with minor thin beds of carbonaceous shale and coal (coal zone 1).	40-70	250-330
2	Sandstone, dark-gray, medium-grained.	25-30	275-360
1 Bottom	Sandstone, light-gray to dark-gray, fine-grained; beds 0.5 m thick; interbedded with argillite; unit contains two carbonaceous shale beds about 0.7 m thick; unit described from drill hole DH-1/11 (see map).	260	535-620

Table 2. Measured stratigraphic section of Upper Triassic coal-bearing rocks in the southeastern block of the Jermanis coal field showing unit number in descending order, unit thickness, and cumulative thickness. Modified after Rudzyanski (1953) and Atabekian and others (1996). For description of coal zones see coal geology section.

Unit number	Description	Thickness (m)	Cumulative thickness (m)
5	Sandstone, gray, coarse-grained; interbedded with minor calcareous sandstones and argillite; overlain by Miocene-Pliocene tuffs.	210	210
4	Argillites, gray; interbedded with gray quartz-feldspar sandstone, carbonaceous shale, and coal (coal zone B).	100	310
3	Sandstone, light-gray to medium-gray, fine- to medium-grained; interbedded with gray argillites.	80-100	390-410
2	Argillites, dark-gray to black; thin beds; interbedded with thin beds of greenish-gray, micaceous, fine-grained, thin-bedded sandstone that contains carbonized plant remnants with minor carbonaceous shale and coal lenses.	110	500-520
1 Bottom	Sandstone, gray, fine-grained; interbedded with argillite, carbonaceous shale, and coal (coal zone A); underlain by Lower to Middle Triassic limestone.	25	525-545

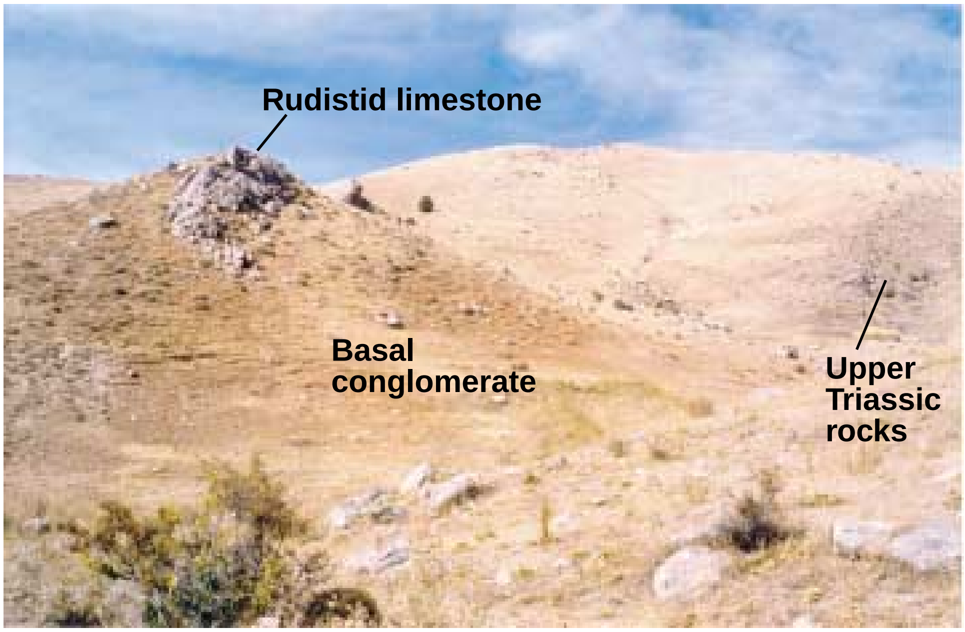

Figure 6. Upper Cretaceous basal conglomerate and rudistid limestone unconformably overlying Upper Triassic rocks in the Jermanis coal field, central Armenia. Upper Cretaceous basal conglomerate is about 20 m thick.

Upper Cretaceous (Turonian?) volcaniclastic rocks (Kvs) crop out in the southwestern part of the study area (see map). The volcaniclastic rocks appear to be conformable with the underlying Upper Cretaceous rocks; although in the southeastern part of the study area there is some evidence that the contact might be unconformable. In the southwestern part of the study area, the contact is sinuous, implying an unconformable contact or a thrust fault. The volcaniclastic unit consists of marine sedimentary rocks that contain medium- to coarse-grained volcanic clasts (tephra and volcanic ash) in an altered tuffaceous matrix. There are also thick units of altered, fine-grained, green and red tuff, which was probably deposited within a marine environment. The total thickness of the volcaniclastic unit is unknown but it might be more than 1,000 m thick and is exposed for several kilometers along the Vedi River south of the Jermanis study area.

Ash-flow and ash-fall tuff of Miocene to early Pliocene age (Tvt) unconformably overlie the Triassic and Upper Cretaceous rocks in the Jermanis coal field. In the central part of the study area, the tuff is in contact with the Lower and Middle Triassic limestone. In the northwestern and southeastern parts of the study area, the tuff is in contact with the Upper Triassic coal-bearing deposits. The Triassic deposits dip to the southeast under the tuff unit. The tuff also overlies the Upper Cretaceous volcaniclastic rocks and the rudistid limestone. The tuff can be divided into two units: a lower unit of weakly welded ash-flow and air-fall tuff and an upper unit of densely welded ash-flow tuff. The lower unit consists of white, coarse-grained, ash-flow tuff containing sand- to pebble-size clasts of pumice and fine to coarse grains of quartz. Planar-bedded ash-fall tuff is present near the base (fig. 7). The lowermost part of the unit was reported to contain beds of diatomaceous clay (Atabekian and others, 1996) and is about 200 m thick. The upper unit consists of dark-gray to light-gray, densely welded, ash-flow tuff containing phenocrysts of biotite, quartz, and plagioclase with minor pumice fragments and is about 40–50 m thick. Based on regional studies (Atabekian and others, 1996), the upper unit is early Pliocene in age.

Middle Pliocene andesite flows (Tva) crop out along a distinct plateau that borders the Jermanis coal field to the north and east (fig. 8). The flows consist of gray and pink andesite; some flows contain large (as long as 0.5 cm) phenocrysts of plagioclase. The flows are best exposed on the eastern and northern margins of the coal field and along the steeper slopes below the plateau and have a composite thickness of 350 m.

A drainage-divide plateau north and east of the mapped Jermanis coal field is underlain by Quaternary lava flows (fig. 3). The flows consist of dense, dark-gray basalts overlain by vescicular basalt and andesite.

Figure 7. Planar-bedded Miocene ash-fall tuffs just east of the outcrop of Lower to Middle Triassic limestone along the Jermanis River north of Jermanis, central Armenia.

Figure 8. Middle Pliocene andesite flows overlying ash-flow tuff in the northeastern part of the Jermanis coal field, central Armenia.

Quaternary hot-spring deposits (Qhs) of travertine crop out in the area just northeast of Jermanis. The deposits developed along a major north-trending fault that separates Upper Cretaceous conglomerate and Lower to Middle Triassic limestone. There are at least five travertine terraces (levels) developed in the southeastern part of coal area. Each terrace is from 10 to 40 m thick. We did not find any active hot springs in the study area.

The central part of the Jermanis coal field is covered by additional Quaternary deposits that include colluvium, talus, and landslide debris (Qc). Talus is found along the base of the plateau that borders the coal field to the east and north. Landslides resulted from the rapid erosion of the friable Miocene ash-fall tuffs causing the collapse of the overlying Pliocene ash-flow tuff. Several lakes have formed in the upper parts of the landslides. Quaternary alluvium (Qal), consisting of gravel, sand, silt, and clay, is present in active streams.

STRUCTURE

The Upper Triassic coal-bearing rocks (TRs) in the Jermanis coal field are exposed on the southern limb of a northwest-trending anticline. The northern limb of the anticline is covered by Miocene-Pliocene tuffs and Quaternary deposits. The nature of this structure is reported by Atabekian and others (1996) and described as a pericline or dome-like structure. The structure was delineated by analyzing several drill holes (DH- 7, 8, 10, and 12, see map) that penetrated Lower to Middle Triassic limestone (TRls) below the Upper Triassic rocks and cross sections were constructed. We suggest that the structure is most likely a fault-modified, southeast-plunging anticline, but because of the limited time in the field and access to detailed drill hole data the anticline axis was not delineated nor mapped.

In the southeastern block of the study area, several minor folds complicate the general southeast dip of the Upper Triassic deposits (Atabekian and others, 1996). These small folds trend under the Upper Cretaceous unconformity. In the northwestern block of Upper Triassic rocks, the general dip is toward the southwest. This dip trend is modified by a small fold that can be traced for a short distance in the southern part of the northwestern block. Because of the limited time in the field these small folds were not mapped.

As reported in Atabekian and others (1996) there are differing opinions on the existence of a major fault separating the Lower to Middle Triassic limestone (TRls) and the Upper Cretaceous deposits (Ks) in the center of the coal field, northeast of Jermanis. Atabekian and others (1996) believe the fault is present. Some investigators believe that the limestone is interbedded with the Upper Triassic deposits (Rudzyanski, 1953) dividing the Upper Triassic coal-bearing sedimentary rocks (TRs) into two parts, and that the Cretaceous deposits are just unconformable on the Triassic rocks and therefore the fault does not exist. This study reviewed the problem in the field and we believe that the fault does indeed exist and divides the coal-bearing deposits into two blocks: the younger northwestern block of Norian age and the older southeastern block of Carnian age

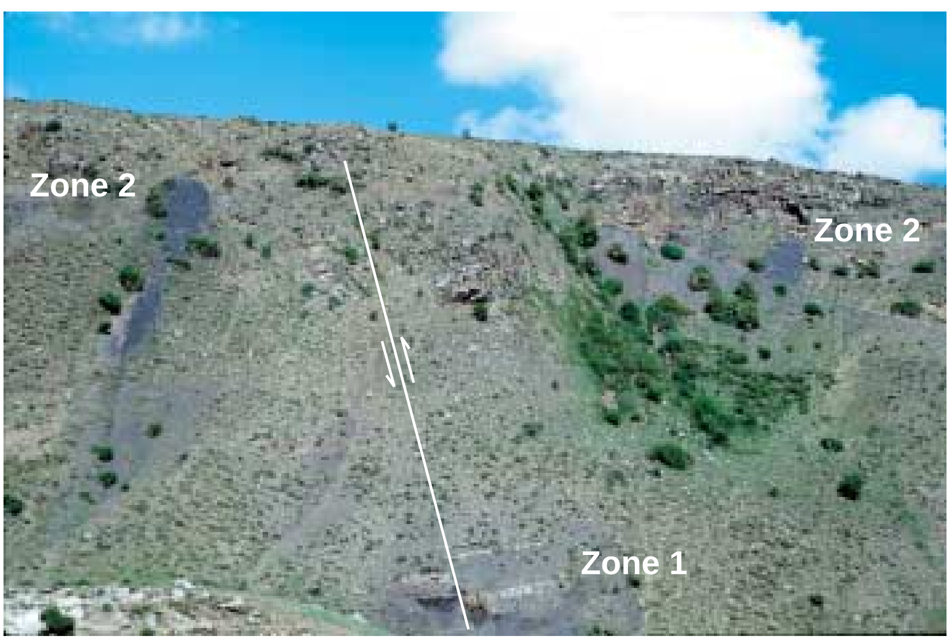

Figure 9. Minor fault and coal zones 1 and 2 in Upper Triassic coal-bearing rocks, northwestern block, Jermanis coal field, central Armenia.

(Azarian, 1962). Other minor faults with small displacements were recognized in the study area by the USGS and previous investigators (see map; fig. 9).

A new major normal fault was mapped during this study in the southwestern part of the Jermanis coal field. This fault follows the Vedi River eastward south of Jermanis and then trends northeastward where it is covered by Quaternary deposits. South of the town of Jermanis the Lower to Middle Triassic limestone is in fault contact with Upper Cretaceous deposits. We discussed the presence of other faulting in the area, but because of the limited time in the field these faults were neither delineated nor mapped.

COAL GEOLOGY

Within the Jermanis coal field there are at least 40 reported outcrops of coal (Atabekian and others, 1996). During the fall of 1998, the authors conducted a field study to reevaluate the coal area. The coal-bearing rocks of the Jermanis area are of Late Triassic age. The coal beds are found in two areas within the study area: the northwestern block and the southeastern block. The two blocks are separated by the Jermanis River (see map). The northwestern block contains at least four coal zones whereas the southeastern block contains at least two coal zones. In this report, the coal-bearing intervals will be referred to as zones because they can contain several thin beds of coal separated by carbonaceous shale. Because of poor exposures, lack of distinct marker beds, complex structure, and lack of deep coal exploration drilling it was impossible to stratigraphically correlate the coal zones between the two blocks, but we agree with previous investigators that the northwestern block is younger than the southeastern block (Atabekian and others, 1996).

The Northwestern Block

The northwestern block is bounded on the southeast by the Jermanis River, on the north by Miocene tuff deposits (Tvt), and on the west unconformably by the Upper Cretaceous deposits (Ks, see map). The Upper Triassic coal-bearing rocks (T̄Rs) dip generally to the southwest beneath the Upper Cretaceous and Quaternary deposits. The Upper Triassic section in the northwestern block is characterized by interbedded fine- to medium-grained sandstone, siltstone, and mudstone of marine and nonmarine origin. The nonmarine rocks contain the coal and carbonaceous shale. The northwestern block contains four coal zones beginning with zone 1 on the base and zone 4 on the top of the section.

Atabekian and others (1996) reported that the coal in zone 1 (their Bed I) was sooty coal and 0.2 m thick. Zone 1 (fig. 10) was examined during this study just south of drill hole DH-1/11 (see map, northwestern block) and we concluded that it was mostly carbonaceous shale with thin coal lenses.

Zone 2 (Bed II of Atabekian and others, 1996) contains the best coal examined in the Jermanis coal field (figs. 10 and 11). This coal zone can be traced for about 1,400 m. The net coal thickness of the zone ranges from 0.2 to 1.2 m and averages 0.5 m along the outcrops north of adit 12 (see map). Zone 2 was found to be continuous for 76 m in adit 12 (see map) with a thickness of about 0.4 m (Atabekian and others, 1996). The zone includes at least three beds of coal interbedded with fine-grained sandstone and carbonaceous shale. Coal-bed splitting, thinning, and pinch outs are observed along the entire outcrop. The zone is characterized by a central bed of coal ranging in thickness from 0.14 to 0.9 m and an upper and a lower bed ranging in thickness from 0.1 to 0.3 m separated by fine-grained sandstone and siltstone beds (Atabekian and others, 1996). A bench sample was collected during this study from the central bed just south of adit 12 (see map, S-3). About 20 m below the outcrop of zone 2 the coal-bearing rocks change to marine facies from which brachiopods were collected.

Zone 3 (Bed III of Atabekian and others, 1996) crops out at the top of the easternmost ridge in the northwestern block (see map). It parallels zone 2 in the southern part of the block. Zone 3 is separated from zone 2 by about 15 m of sandstone. Along the northern half of the outcrop, Atabekian and others (1996) reported that the zone ranges from 0.2 to 0.45 m in thickness and is underlain by carbonaceous shale beds from 0.4 to 0.5 m thick. Zone 3 was traced for more than 72 m down dip in exploration adit 17 (see map) and averages about 0.4 m thick (Atabekian and others, 1996). Zone 3 pinches out to the west and was not penetrated by drill hole DH-4 (see map).

Figure 10. Upper Triassic coal-bearing deposits in the northwestern block of the Jermanis coal field, central Armenia. Zone 1 is in the foreground with zone 2 above. The Jermanis mine is located in the upper left corner of the photo.

Figure 11. Zone 2 coal (Bed 2 of Atabekian and others, 1996) just south of the old exploration adit (adit 12, see map), northeast of Jermanis in the northwestern block of the Jermanis coal field, central Armenia.

Zone 4 (Bed IV of Atabekian and others, 1996) crops out about 50 m above zone 3 in the southern part of the northwestern block. It was visible in collapsed trenches and adits developed during the middle 1990’s. Only small fragments of coal were visible in old dumps. The zone was described by Atabekian and others (1996) as a sooty coal bed ranging from 0.2 to 0.3 m thick. The bed pinches out rapidly to the north and south and therefore has no economic value according to Atabekian and others (1996).

The Southeastern Block

The southeastern block in the Jermanis coal area is bounded on the north by Quaternary deposits (Qc) and on the south by Upper Cretaceous sedimentary (Ks) and volcaniclastic rocks (Kvs). To the east, the coal-bearing rocks are overlain by Miocene to lower Pliocene rocks (Tvt) and to the west, the coal-bearing section is underlain by Lower to Middle Triassic limestone (T̄Rls, see map). Generally the coal-bearing section dips to the southeast under the Upper Cretaceous deposits and Miocene tuff. Coal was mapped in two zones in the southeastern block: zone A (Bed 1 of Atabekian and others, 1996) located near the basal contact of the unit and zone B (Beds 2 and 3 of Atabekian and others, 1996) in the upper part of the coal-bearing unit, about 265 m above zone A.

Zone A consists of at least three beds of coal separated by carbonaceous shale and thin sandstone beds. Zone A’s outcrop line is cut by a minor northwest trending fault that has displaced the coal zone by about 60 m to the northwest (see map). Only collapsed adits and trenches were visible at the time of this investigation and a grab sample of coal was collected at adit 31 (see map, S-2) for chemical analysis. Atabekian and others (1996) described the adit as being 90 m long. The adit exposed three beds of coal. The lower bed, about 0.4 m thick, was encountered in a crosscut and consists of hard, bright coal containing pyrite. The middle bed is overlain by a 0.5-m-thick sandstone and is separated from the lower bed by a 2- to 3-m-thick fine-grained sandstone (averages 2.5 m) containing carbonaceous shale and coal lenses. The middle bed’s thickness ranges from 0.2 to 0.4 m (averages 0.28 m). The upper coal bed ranges in thickness from 0.25 to 0.35 m (averages 0.29 m) and is overlain by fine-grained sandstone. Atabekian and others (1996) report that zone A pinches out to the southeast. Drill holes DH-7 (see map, TD (total depth) 250 m) and DH-12 (see map, TD 477.9 m) did not penetrate coal but drill hole DH-5 (TD 306.2 m) penetrated two 0.5-m-thick carbonaceous shale beds at a depth of about 439 m. This carbonaceous shale zone may represent the down-dip continuation of zone A.

Zone B (Beds 2 and 3 of Atabekian and others, 1996) is bounded on the north and northeast by Quaternary deposits (Qc) and is overlain by Miocene tuff (Tvt) to the east and southeast. Several collapsed adits and exploration trenches were observed along the outcrop line (fig. 12). The coal zone consists of at least two coal beds that are present about 250–280 m above zone A. The zone can be traced for about 750 m in a northeast-southwest direction. The lower coal bed in zone B is reported by Atabekian and others (1996) to range in thickness from 0.2 to 1.4 m. The lower bed is thickest at the northeastern end of the outcrop where it averages 0.5 m thick; the bed thins to 0.2 m at the southern end of the outcrop. The upper bed (Bed 2 of Atabekian and others, 1996) was observed on outcrop where it consisted of a thin sooty coal a few centimeters thick. However, the upper bed was reported by Atabekian and others (1996) to be 0.1–0.5 m thick and about 1.5–5.5 m above the lower bed. Two grab samples were collected for chemistry at adits 33 and 35 (see map, S-1 and S-4, respectively).

Drill-hole data from the southeastern block (Atabekian and others, 1996) indicates that the coal in zone B is not continuous down dip. Drill hole DH-3 (see map, TD 365 m) penetrated a thin carbonaceous shale at about 100 m depth where the zone was projected at depth, whereas drill hole DH-9 (TD 371.5 m) did not penetrate coal or carbonaceous shale; this suggests that the zone is pinching out to the northeast and thinning to the southeast. Drilling to the east of zone B (DH-13, see map) stopped short of penetrating the projected coal interval but did penetrate barren Upper Triassic rocks in the lower one-third of the hole (Atabekian and others, 1996).

Figure 12. Adit 33 in coal zone B (see map) in the southeastern block of the Jermanis coal field, central Armenia. Zone B consists of at least two coal beds ranging in thickness from 0.1 to 0.5 m.

Discussion

During the USGS study of the Jermanis coal field it was determined that the coals are thin and contain many partings. The coals have a net-coal thickness that ranges from 0.20 to 0.41 m (Atabekian and others, 1996) and are extremely lenticular. The structure of the coal field is complex, and fracturing and boudinage are evident in the coal and in some cases the coal beds are offset along the outcrop. Because of these factors we don't recommend further exploration except for local use.

Two previous studies calculated coal resources for the coal field to be 2.0 million (Nazarian, 1941) and 328,000 (Tsetlin and Epstein, 1940) metric tons. Atabekian and others (1996) recalculated the reserves based on the exploration carried out in 1939–1940 (Nazarian, 1939, 1941; Mokrinski, 1940; Tsetlin and Epstein, 1940), 1951–1953 (Rudzyanski, 1953), 1966–1971 (Airapetian, 1967; Airapetian and Pogosian, 1968; Mkrtchian and Khachatrian, 1972), and 1992–1994 (Atabekian and others, 1996) using standard methods of the former USSR Commission of Reserves and reported an estimated coal reserve of 393,414 metric tons. Atabekian and others (1996) concluded that the Jermanis coal field had no commercial value and that no further exploration was recommended because the resource was small and the structure was too complex. The USGS did not calculate coal resources for the Jermanis coal field.

COAL QUALITY

Atabekian and others (1996) summarized data from 160 proximate coal analyses in the Jermanis coal field (analyzed basis was not given). Moisture content in the coal is low and ranges from 0.14 to 7.8 percent and the ash yield ranges from 11.1 to 49.1 percent with an average ash yield of about 36.6 percent. Zone A coals in the southeastern block have the lowest ash yields ranging from 11.1 to 28.1 percent (average 17.4 percent). The Zone 2 coal beds in the northwestern block are high in ash, with ash yields ranging from 26.7 to 49.1 percent (average 41.5 percent). Zone B coal in the southeastern block has the lowest total sulfur content at 0.9 percent. The other beds in the coal field range from 1.4 to 2.9 percent sulfur. Heat-of-combustion values range from 7,450 to 8,830 kcal/kg (13,410 to 15,894 Btu/lb) on a moist, mineral-matter-free basis (Atabekian and others, 1996). The apparent rank of the coals, which was determined using the Parr formula (American Society for Testing and Materials (ASTM), 1998, D388-98), ranges from-high volatile B to high-volatile A bituminous.

The USGS sampled and analyzed coal from zone 2 in the northwestern block (Pierce and others, 1994). Three coal beds and one carbonaceous shale bed were sampled south of adit 12 (see map). The results of the coal analyses on an as-received basis indicate a moisture content ranging from 3.79 to 5.17 percent (average 4.75 percent), an ash yield ranging from 8.52 to 47.14 percent (average 27.7 percent), and a sulfur content ranging from 0.33 to 0.52 percent (0.39 percent). The heat-of-combustion values range from 7,269 to 7,899 kcal/kg (13,048 to 14,218 Btu/lb) on a moist, mineral-matter-free basis. The apparent rank ranges from high-volatile B to high-volatile A bituminous.

Atabekian and others (1996) reported some spectral analysis data on an ash basis for seven metals from seven coal samples from the Jermanis coal field. Results are: cobalt (100–1,000 ppm), gallium (10–1,000 ppm), germanium (1 ppm), nickel (100–1,000 ppm), tungsten (0–1,000 ppm), and vanadium (100–10,000 ppm).

Three grab samples (S-1, 2, and 4, zones A and B, southeastern block) and one bench sample (S-3, zone 2, northwestern block) were collected during this study for major-, minor-, and trace-element analysis. The results of these analyses on an ash basis are shown in table 3.

Discussion

Based on USGS analyses of all coals analyzed in Armenia (Pierce and others, 1994), the Jermanis coal beds have the highest apparent rank (high-volatile A and B bituminous). The low sulfur content (less than 0.52 percent) in the USGS sample analyses (Pierce and others, 1994) was much lower than the values reported by Atabekian and others (1996). High total sulfur contents (as much as 2.91 percent) reported by previous Armenian workers are probably related to the high content of pyrite in the coal observed on the outcrop. Ash yields are high and variable (average 36.58 percent), reflecting the influence of numerous thin partings and boney coal within the coal beds. Cleaning the coals prior to utilization is not recommended because the net-coal thickness of the beds is thin (less than 0.5 m) and the beds are very lenticular.

A comparison of the mean content of elements of environmental concern for the zone 2 and zone A coal beds with Cretaceous coal from the Colorado Plateau (Affolter, in press) is shown in table 4. Most of the elements in the Jermanis coal compare favorably with those in the Cretaceous Colorado Plateau coal. Only four elements (As, Be, Co, and Cr) are slightly higher in coal from Jermanis than in the coal from the Colorado Plateau. The As and Co are most likely associated with the abundant pyrite present in the Jermanis coal beds and the Be and Cr are probably associated with detrital minerals present in the same coal. The Colorado Plateau coal beds are an important resource used for power generation in the Western United States. The Cretaceous coal beds generally contain less sulfur (0.7 percent) and ash (12.9 percent, based on ash yields less than 50 percent) and have a lower heat content (5,830 kcal/kg or 10,490 Btu/lb) when compared to the Jermanis coal.

CONCLUSIONS

The maximum net-coal thickness observed at the Jermanis coal field does not exceed 0.5 m, dips are generally greater than 15°, and the areal extent of the coal probably does not extend much beyond the mapped area (see map). It is possible that the coal-bearing unit extends to the southwest and southeast under the younger units. However, if the coal-bearing unit does extend beyond the mapped margins, the coal is most likely to be thin and lenticular. Average ash yield is 36 percent and sulfur content ranges from 0.33 to 2.9 percent. Previous studies determined reserves for the Jermanis coal field and concluded that they were small and highly variable. On the basis of these data and observations, we believe that the coal resources in the Jermanis coal field are probably of local importance only.

Table 3. Major- and minor-oxide and trace-element contents of coal samples from the Jermanis coal field, central Armenia. [Cl, Hg, and Se on whole coal; all other values on laboratory coal ash. Sample locations shown on map. < means less than value, a value below detection limit for the element]

	S-3, adit 12 NW block-Zone 2	S-2, adit 31 SE block- Zone A	S-1, adit 33 SE block-Zone B	S-4, adit 35 SE block-Zone B
	Major and minor oxides, in percent			
Ash	13.5	10.5	64.9	57.1
SiO_2	38	56	66	61
Al_2O_3	17	31	22	26
CaO	0.44	2.6	0.53	0.57
MgO	0.70	0.60	1.5	1.7
Na_2O	0.14	0.36	0.79	0.31
K2O	3.6	0.69	3.6	4.6
Fe_2O_3	13	7.2	5.8	4.2
TiO_2	0.71	4.6	0.84	0.89
P_2O_5	0.05	1.3	0.15	0.09
	Trace elements, in parts per million			
Ag	< 2	4	< 2	< 2
As	290	20	10	10
Au	< 10	< 10	< 10	< 10
B	70	130	130	110
Ba	340	460	390	420
Be	16	17	3	4
Bi	< 2	< 2	< 2	< 2
Cd	< 0.8	< 0.8	< 0.8	< 0.8
Cl	7.2	5.0	< 1.5	1.6
Co	16	67	29	22
Cr	180	200	110	120
Cs	17	1	15	21
Cu	130	34	49	53
Ga	56	93	36	40
Ge	33	27	5.9	8.0
Hg	0.10	0.06	0.17	0.67
Li	43	210	150	230
Mn	59	200	540	150
Mo	25	4.2	2	2
Nb	30	110	20	20
Ni	33	47	64	51
Pb	43	30	41	50
Rb	160	23	180	210
Sb	15	< 2	< 2	< 2
Sc	56	72	20	26
Se	1.3	0.24	0.57	0.72
Sn	< 10	< 10	< 10	< 10
Sr	180	4100	150	150
Te	< 2	< 2	< 2	< 2
Th	22	17	12	18
Ti	2	< 2	< 2	< 2
U	10	6.6	3	3
V	370	420	190	230
Y	92	100	18	21
Zn	43	37	90	61
Zr	120	530	180	230

Table 4. Comparison of the mean content of elements of environmental concern (as defined by the 1990 Clean Air Act Amendment) for the zone 2 and A coal beds in the Jermanis coal field, Armenia, and Cretaceous (n=1265) coal from the Colorado Plateau, United States (Affolter, in press). [All elements are in parts per million (ppm) on a whole coal basis; all coal ash yields are less than 50 percent.]

Element	S-3, adit 12 NW block-zone 2	S-2, adit 31 SE block-zone A	Cretaceous Colorado Plateau mean
As	39	20	1.6
Be	2.2	17	1.2
Cd	0.05	0.04	0.1
Co	2.2	7.0	1.5
Cr	24	21	4.5
Hg	0.01	0.01	0.06
Mn	8.0	21	22
Ni	4.5	4.9	3.7
Pb	5.8	3.2	6.5
Sb	2.0	0.11	0.5
Se	0.18	0.03	1.2
U	1.4	0.69	1.3

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